Alcator C-MOD

Mini-Proposal

Subject: Driven and Intrinsic SOL Fluctuation Propagation Experiments **MP No.** ______

From: R. Bengtson, B. LaBombard, W. Rowan

Date: June 2, 1997

Approved by: ______________________ **Date Approved:** ______________

1. Purpose of Experiments

- Develop the facility for tagging a magnetic field line in the SOL

- Use the technique to measure the parallel wavenumber of the plasma turbulence as a function of position in the SOL

- Assess the capability for determining variation in stochasticity near the separatrix

2. Background

Turbulence drives transport in the SOL. For example in TEXT-U, both particle transport[1] and energy transport[2] in the plasma periphery were due to electrostatic turbulence. It follows that we want to know as much about the turbulence as possible so that we can speculate on its origin and its implications for other devices. One parameter that has avoided accurate measurement is the parallel wavenumber. TEXT measurements[3] led to the conclusion that $k_{\|} \ll k_{\perp}$. In this experiment, two probes were placed on the same field line. The phase difference between the two probes was measured for the turbulence spectrum and then compared with the spatial separation of the probes. The difficulty for these and subsequent measurements was that the two probes are far apart but must be placed on the same field line with great accuracy.

On TEXT-U, we developed a new technique for measurement of $k_{\|}$ based on the use of driven probes. In these experiments, two probes are used that are widely separated toroidally. We found that a field line could be tagged by using one of the measuring probes to drive a single frequency and detecting it with the other. Since the signal propagates as an Alfven wave along the magnetic field line, the maximum correlation between transmitted signal and detected signal will define the field line. The correlation between the two probes for the background turbulence will maximize at a location that is not on the field line due to finite $k_\perp$ for the turbulence. $k_\parallel$ is inferred from the distance between the probes and from $k_\perp$ which is measured separately.

Measurements on TEXT showed that the correlation between the driver and the receiver for the driven signal decreased for radii closer to the separatrix. This may be due to enhanced stochasticity near the separatrix. This experiment may provide us with data to investigate this further.

3. Approach

A current driven at a single frequency in the range from 20 kHz to 40 kHz will be launched from a tile probe. A scanning probe will be used to detect the signal. Since the signal propagates as an Alfven wave along the magnetic field line, the maximum correlation between transmitted signal and detected signal will define the field line. The correlation between the two probes for the background turbulence will maximize at a location that is not on the field line due to finite $k_\perp$ for the turbulence. $k_\parallel$ is inferred from the distance between the probes and from $k_\perp$ which is measured separately. In the course of the experiment, the plasma current or toroidal field will be varied by a few percent as a means of scanning for the magnetic field line. Also, it is likely that different frequencies will be launched from each of several tile probes to increase the amount of useful data acquired on each shot.

4. Resources

4.1 Machine and Plasma Parameters

Toroidal Field: 5.3 tesla (see below)

Plasma Current: 1.1 MA (see below)

Working gas species: deuterium

Density: NeBar above 1.2×10^{20} m^{-3} (conduction-limited divertor regime)

Equilibrium configuration:

Lower X-point diverted discharge similar to shot 960130014 with 2 cm inner and

outer gaps, strike points on outer divertor probe #2 and inner divertor probe #1, and feedback control on outer strike-point position.

Specific Requirements

The magnetic field structure in the scrape-off layer must be set up to allow field lines to connect from the K- and/or F-port scanning probe to one of the outer divertor probes. Figure 1 shows a field line ‘puncture-plot”, tracking fields lines originating from divertor probe locations to other toroidal locations in the outer SOL. The 1.1 MA, 5.3 tesla discharge shown has fields lines mapping near to the K-port and F-port scanning probe locations. The mapping depends on strike-point location as well as the toroidal and poloidal field structure.

An additional complexity arises from the magnetic shear near the separatrix and the near-vertical divertor target. Field lines from multiple divertor probes can simultaneously map onto a scanning probe trajectory, albeit on different flux surfaces. Figure 1 shows field lines mapping from outer divertor probes #3 and #7 onto the F-port scanning probe trajectory. One field line has a 7.5 meter length while the other has a 4 meter length. In this case, the techinque of using different driver frequencies on the divertor probes will be useful to separate the mapping.

Decreasing the toroidal field by 2%, one obtains the field line mapping shown in figure 2. The 'puncture-points" correspondingly move poloidally by 2 to 3 cm.

The equilibrium shown in figure 1 had $q_{\psi 95} \sim 3.2$, elongation ~ 1.6 and lower triangularity ~ 0.56. Discharges with different currents and toroidal fields could also be used, provided the above geometrical parameters are about the same.

Pulse length, typical current & density waveforms, etc.

1 sec current 'flat-top" with a 2% ramp in toroidal field or plasma current

4.2 Auxiliary Systems

RF Power, pulse length, phasing: none

Pellet Injection (species): none

Impurity blow-off injection: none

Special gas puffing: none

Other:

4.3 Diagnostics

The standard set of core plasma diagnostics will be required. Particular focus is on the K- and F- port scanning probes and the outer divertor probe array:

K-port and F-port Fast-Scanning Probes

- Adjust LCFS target, probe insertion depths, and timing to yield three probe insertions per shot.

- Configure electronics and fast CAMAC to record I_{sat} and V_f fluctuations.

Outer Divertor Probe Array

- Set up 20kHz to 40kHz voltage waveforms on one or more probes. (This could be done using the 'DC supply" inputs on the front of the electronics cards.)

- In order to maximize the driven waves, the probes will be biased towards electron saturation. Without care, this operation could damage the probes. Thus, experiments in moderate to high density (low divertor T_e), ohmic heated discharges are the best choice.

4.4 Neutron Budget

Same as previous runs

5. Experimental Plan

5.1 Run sequence plan

For the initial set of experiments, data will be collected in a 'piggy-back" mode. As the diagnostic techniques become refined, a few dedicated runs will be requested.

5.2 Shot sequence plan

In 'piggy-back' mode:

- Look for runs calling for equilibria with $q_{\psi 95} \sim 3.2$, elongation ~ 1.6 and lower triangularity ~ 0.56.

- Examine detailed field-line mapping before and during run.

- Convince primary session leader to use strike-point feedback and to program 2-5% toroidal field or plasma current ramp.

- Convince primary session leader to insert scanning probe(s) and take data.

- Write proposal to request dedicated runs as appropriate.

6. Anticipated Results

We expect to measure $k_{||}$ as a function of radius in the SOL. This will be coupled with other measurements of turbulence to provide a characterization of turbulence and turbulence driven flux for a number of different discharge conditions. The magnitude of $k_{||}$ may suggest a spatial location for the turbulence drive. Since parallel wave numbers for the turbulence are small, the turbulence drives may be well separated from the point of observation—as far away as the divertor plates or the limiter. This would be taken as a clue to look at the effects of divertor plates and sheath.

7. References

1 W.L. Rowan, et al., Nuclear Fusion **27**, 1105 (1987).

2 Ch.P. Ritz, et al., Phys. Rev. Lett. **62**, 1844 (1984).

3 R.D. Bengtson, private communication concerning Langmuir probe measurements; P.D. Hurwitz, private communication concerning D_α fluctuation measurements.